

Photoemission studies of 2H-TaSe_2 in the normal and Charge Density Wave states

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Motivations and Questions

- ✓ **CDW coexists with superconductivity:**
 $T_{\text{CDW}} \sim 122 \text{ K}$; $T_{\text{SC}} \sim 0.15 \text{ K}$
- ✓ **What drives the CDW transition:**
“Conventional” Fermi surface nesting or
“saddle point” nesting?
- ✓ **CDW does not remove the entire Fermi surface:** What happens to the excitations at the Fermi energy in a presence of the CDW gap?

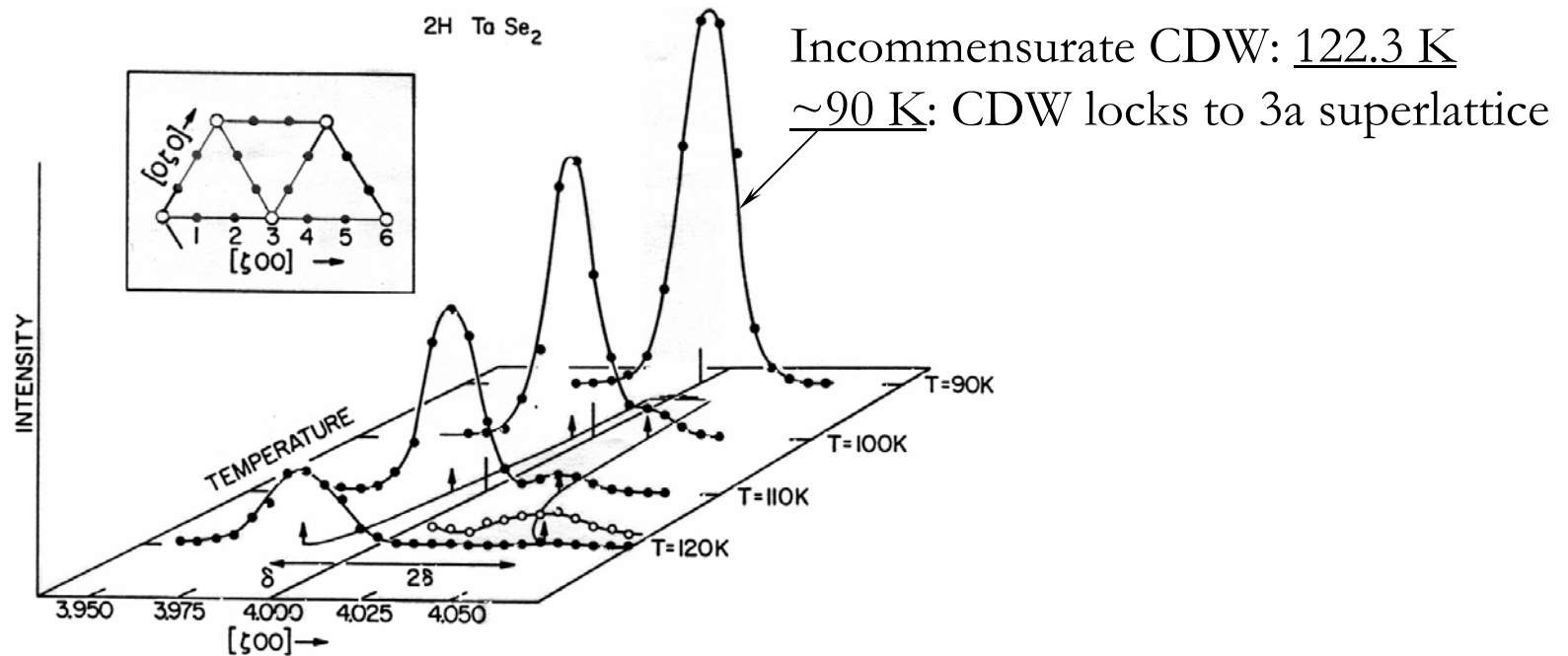
Outline

- ✓ **Introduction**
CDW, Fermi surface, nesting
- ✓ **Experiment**
ARPES spectrometer
- ✓ **Results**
band mapping, band folding,
coupling of quasiparticles to
excitations specific to the CDW
state
- ✓ **Is it similar to the HTSC?**

Neutron scattering experiment

/superlattice due to the Charge Density Wave/

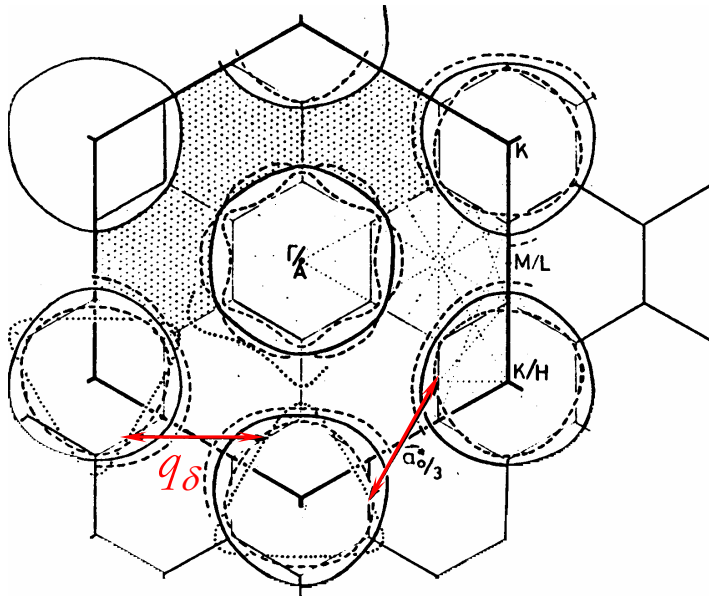
D.E. Moncton, J.D. Axe, and F.J. DiSalvo, PRL 34, 734 (1975)



$$\text{CDW wave vector: } q_{\delta} = 4\pi \{1 - \delta(T)\} / a\sqrt{3}$$

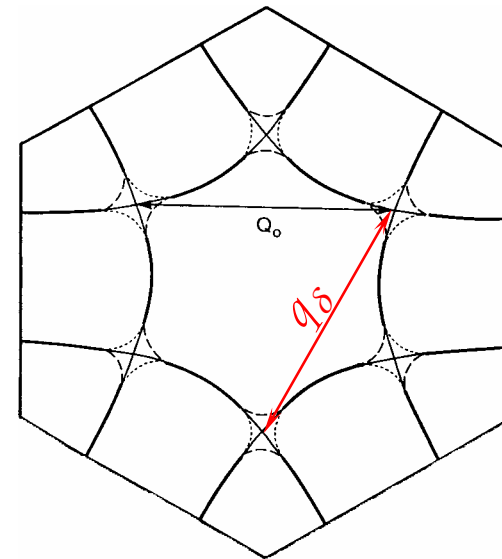
Nesting

A. Fermi surface nesting



J.A. Wilson, PRB 15, 5748 (1977)
G. Wexler and A.M. Wooley, J. Phys.
C 9, 1185 (1976)
L.F. Mattheiss, PRB 8, 3719 (1973)

B. “Saddle point” nesting

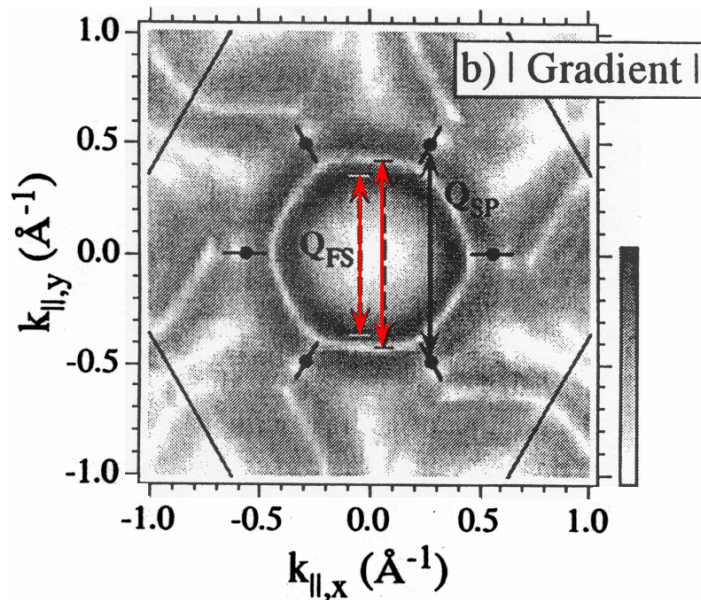


T.M. Rice and G.K. Scott,
PRL 35, 120 (1975)

What is known?

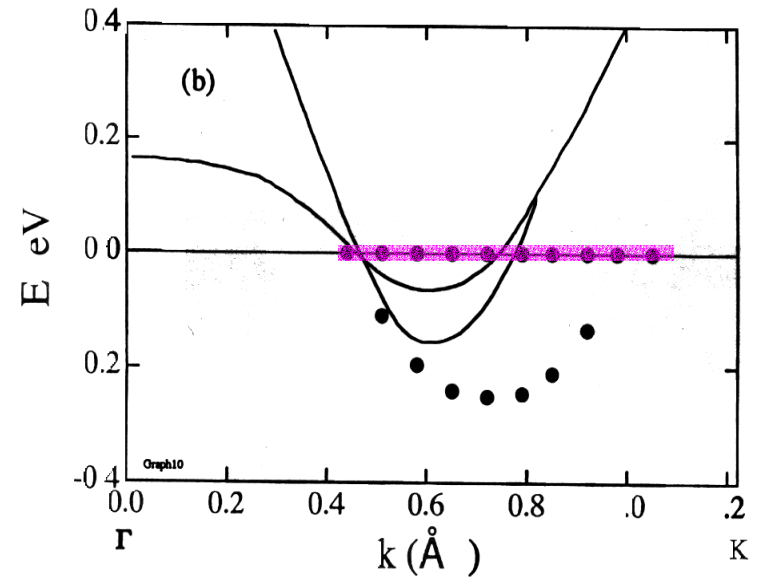
/ARPES studies/

A. “Regular” nesting



Th. Straub et al., PRL 82, 4504 (1999)

B. Saddle band \Rightarrow Rice-Scott model

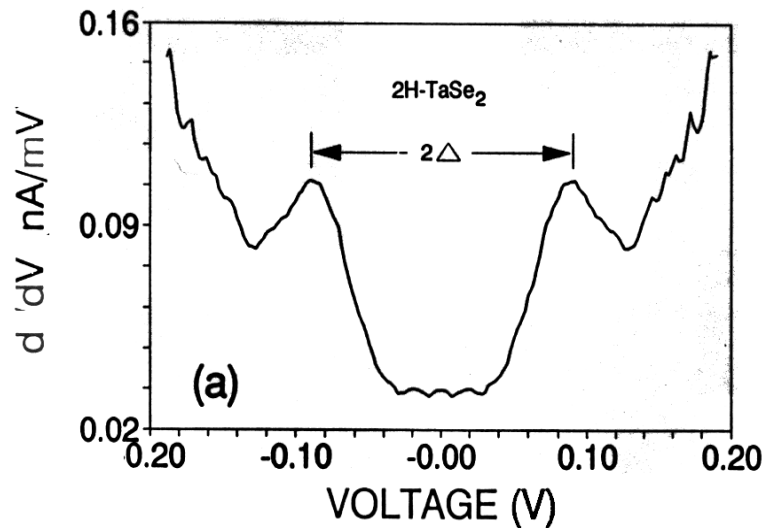


Rong Liu et al., PRL 80, 5762 (1998)

$0.69 \text{ \AA}^{-1} < q_{\delta} < 0.87 \text{ \AA}^{-1} \Leftrightarrow \text{Problems} \Rightarrow$ Saddle band, not a point

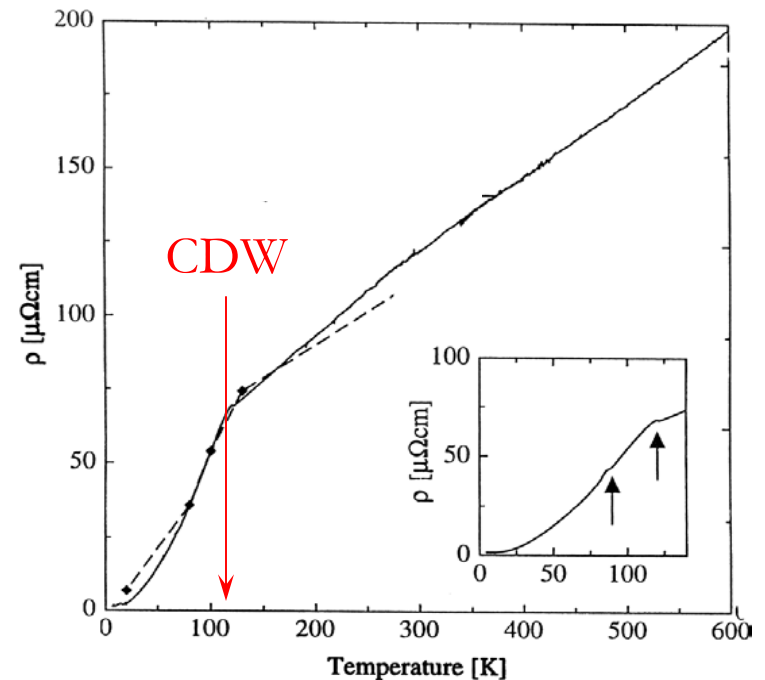
What does CDW do?

Opens up a gap, $2\Delta \sim 150$ meV
/STM data/

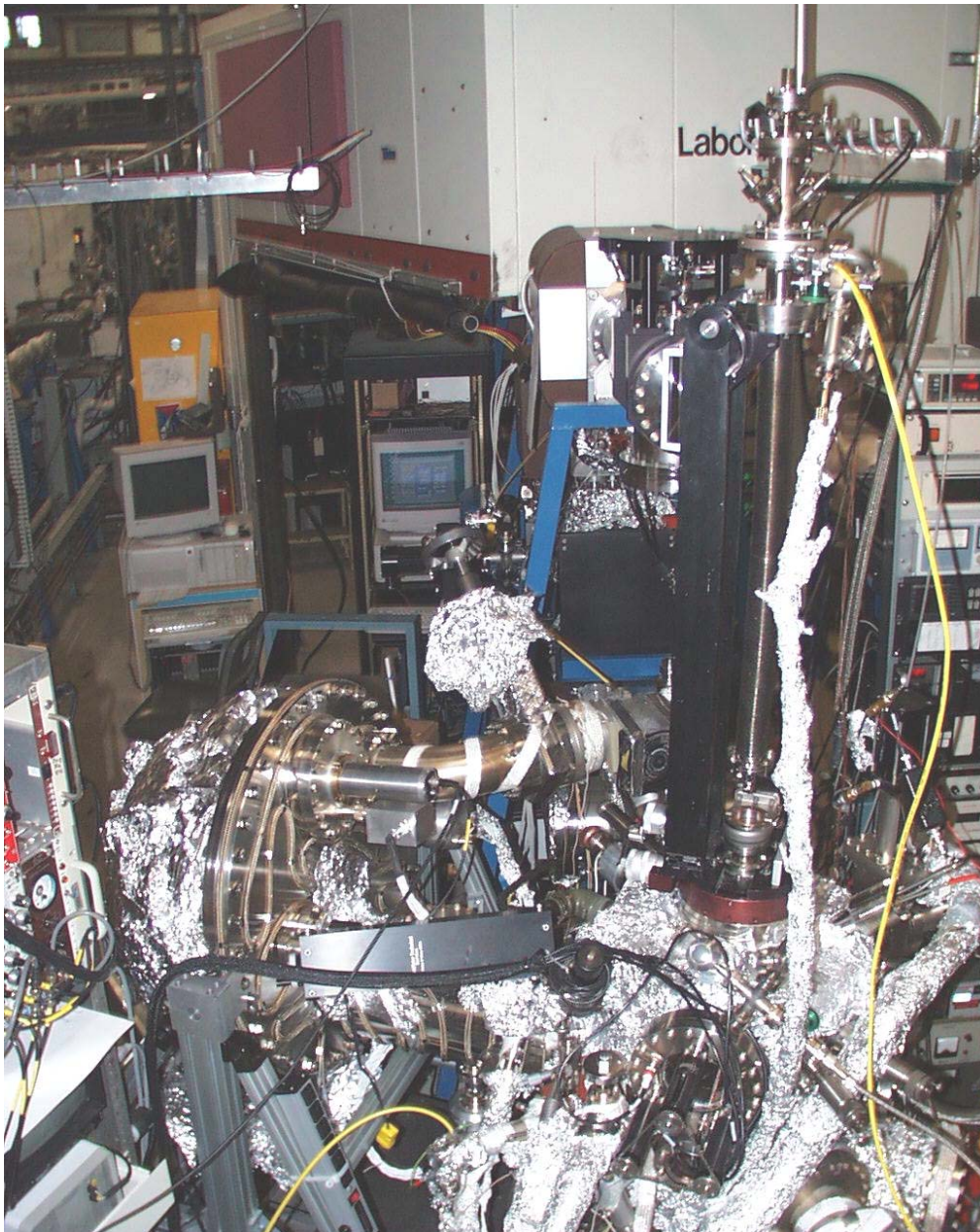


Z. Dai et al., PRB 48, 14543 (1993)

Freezes out scattering channels
/transport measurements/



V. Vescoli et al., PRL 81, 453 (1998)



Experiment

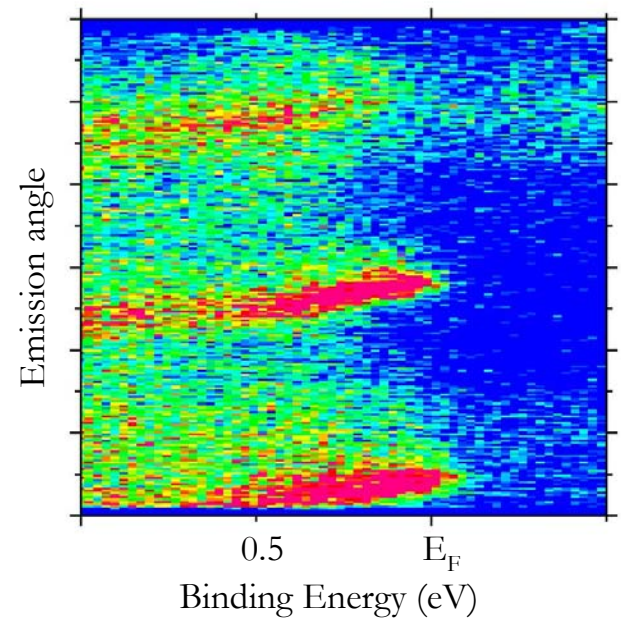
ARPES chamber with
Scienta 200-mm analyzer

Performance:

$$\Delta E \sim 10 \text{ meV}$$

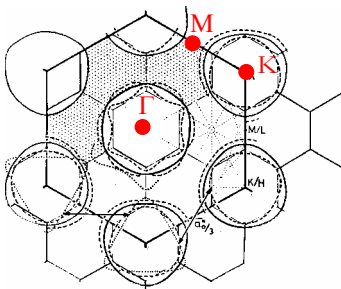
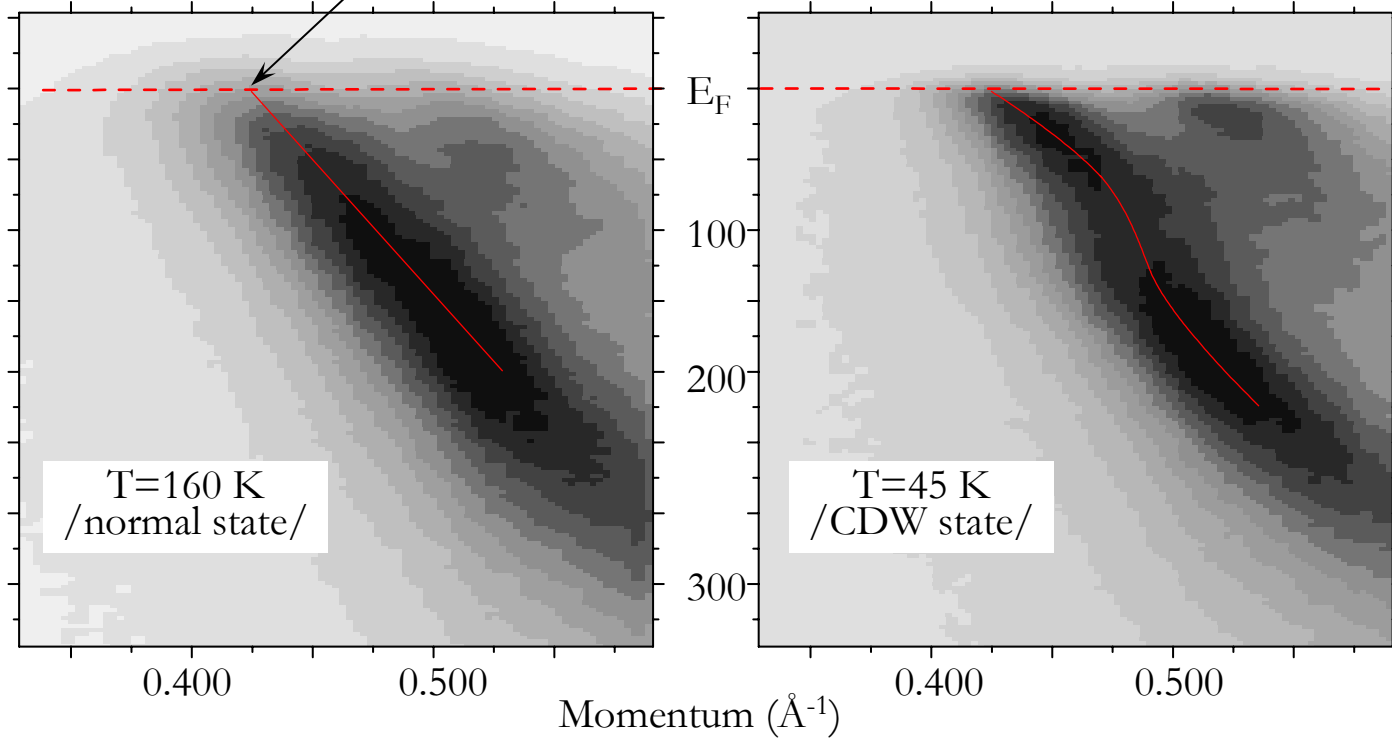
$$\Delta \Theta \sim 0.2^\circ$$

$$3 \times 10^{-11} \text{ Torr}$$

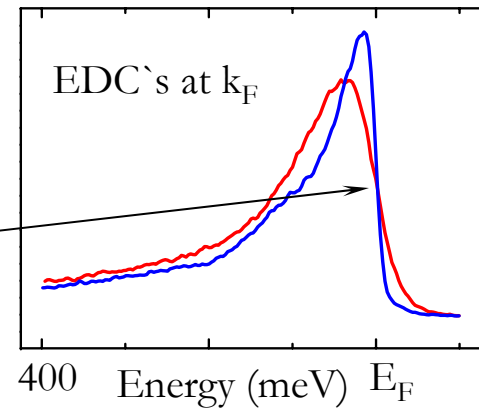


Band mapping along ΓM

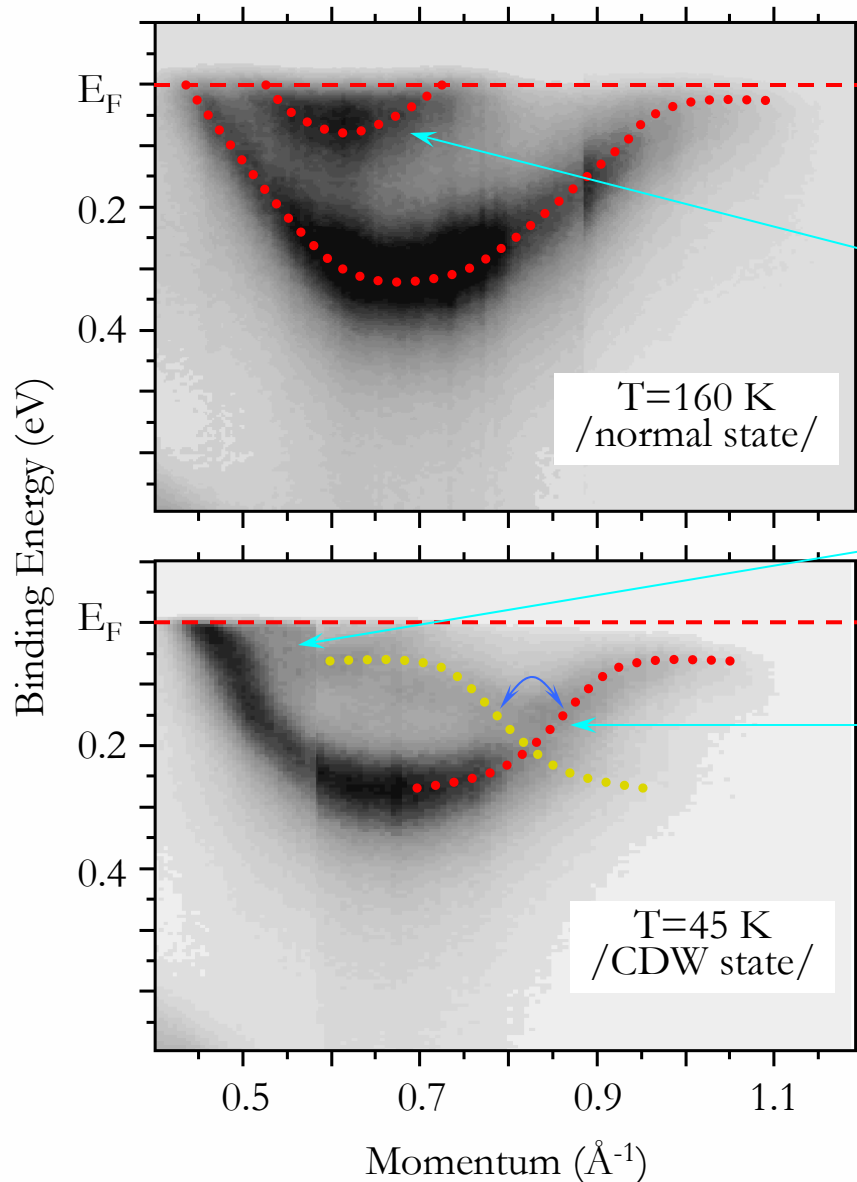
Fermi level crossing: $k_F = 0.425 \text{ \AA}^{-1}$



Nesting along ΓM is not very good and there is no gap at the Fermi level...



Band mapping along ΓK



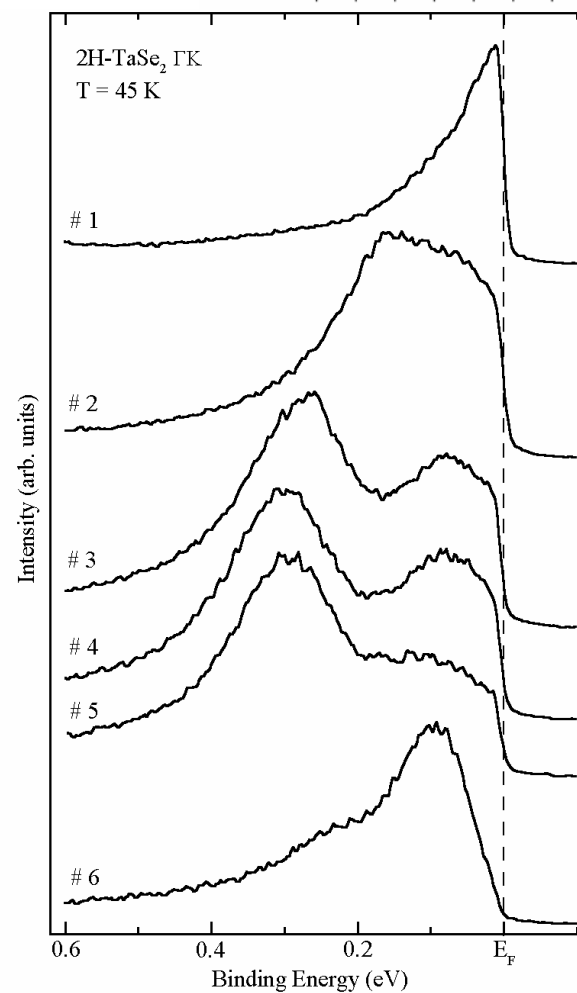
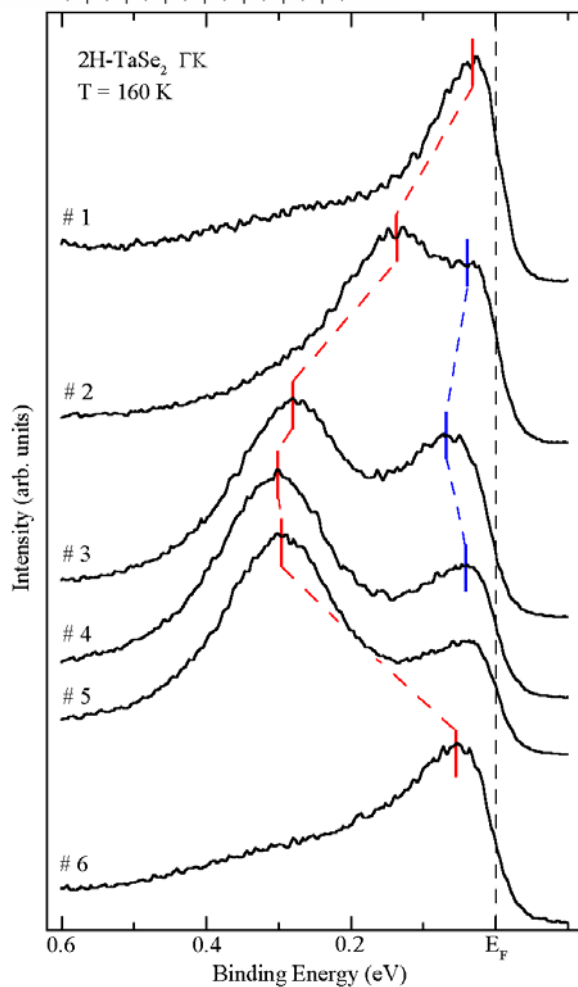
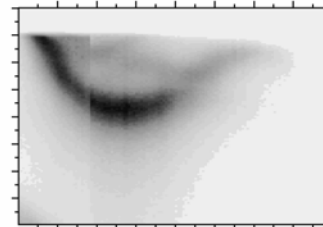
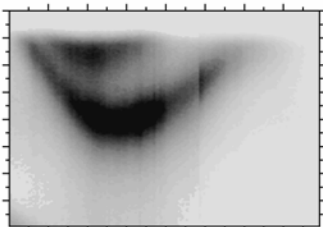
New results:

- Saddle point has a bandwidth of just $\sim 50 \text{ meV}$ and extends for only 0.2 \AA^{-1}
- It is no longer there in the CDW-state
- Band “folds back” at $\sim 0.825 \text{ \AA}^{-1}$; This projects into $\sim 2/3$ of ΓM



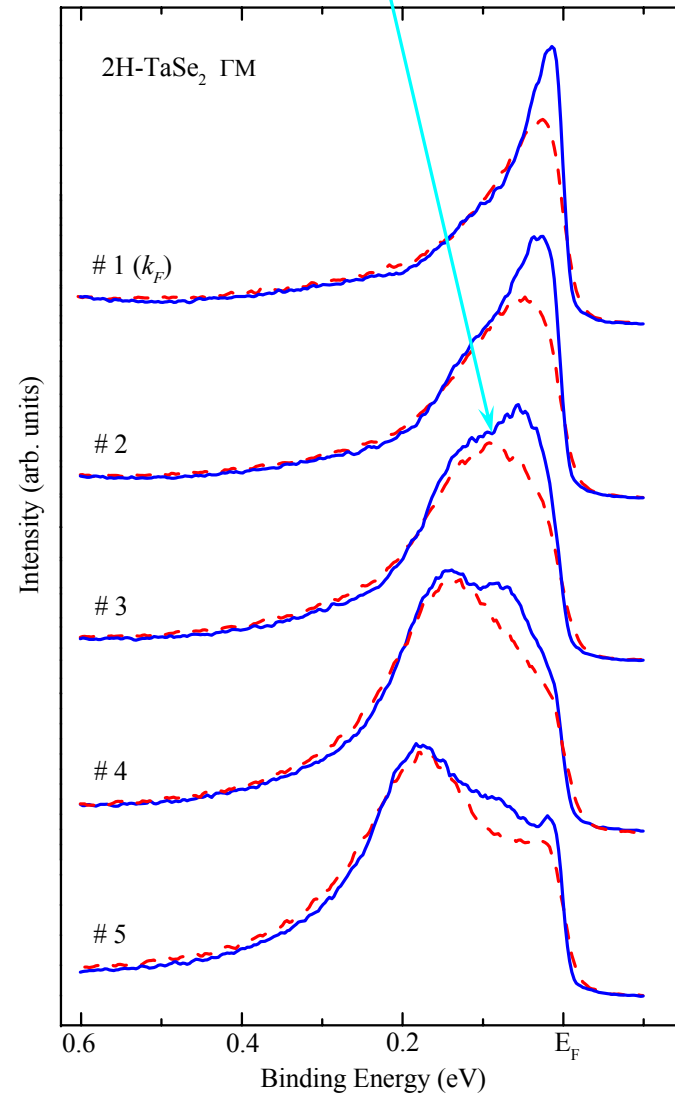
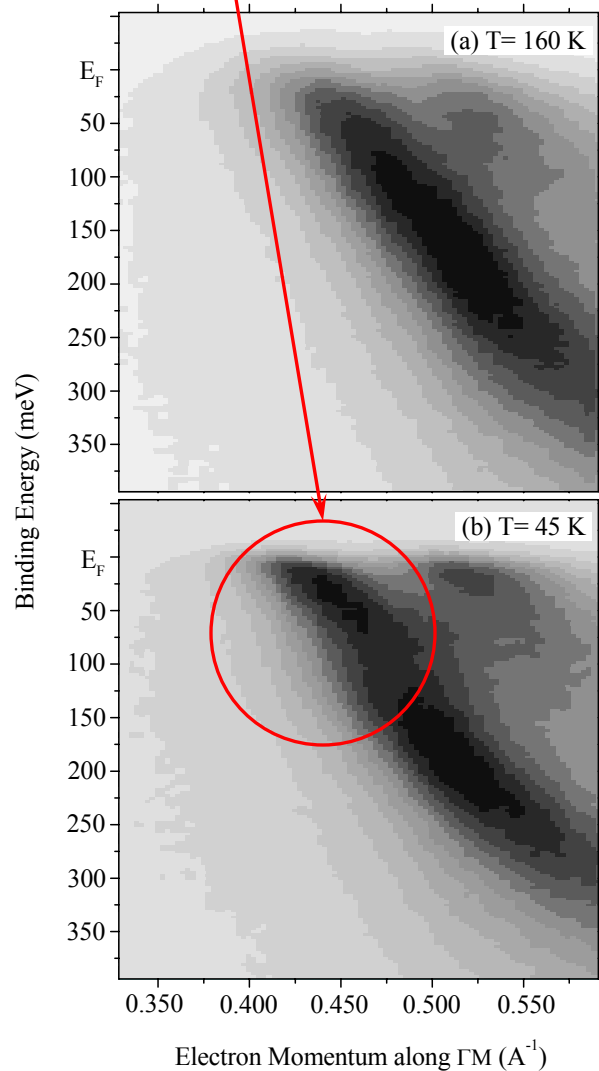
These observations point towards the Rice-Scott model

Energy distribution curves
at few interesting points
along ΓK



How does CDW affect low-energy excitations?

At **45 K** coupling of quasiparticles to the collective mode of some sort manifests itself via changes of both, ARPES **line-shapes** and **dispersion relations**

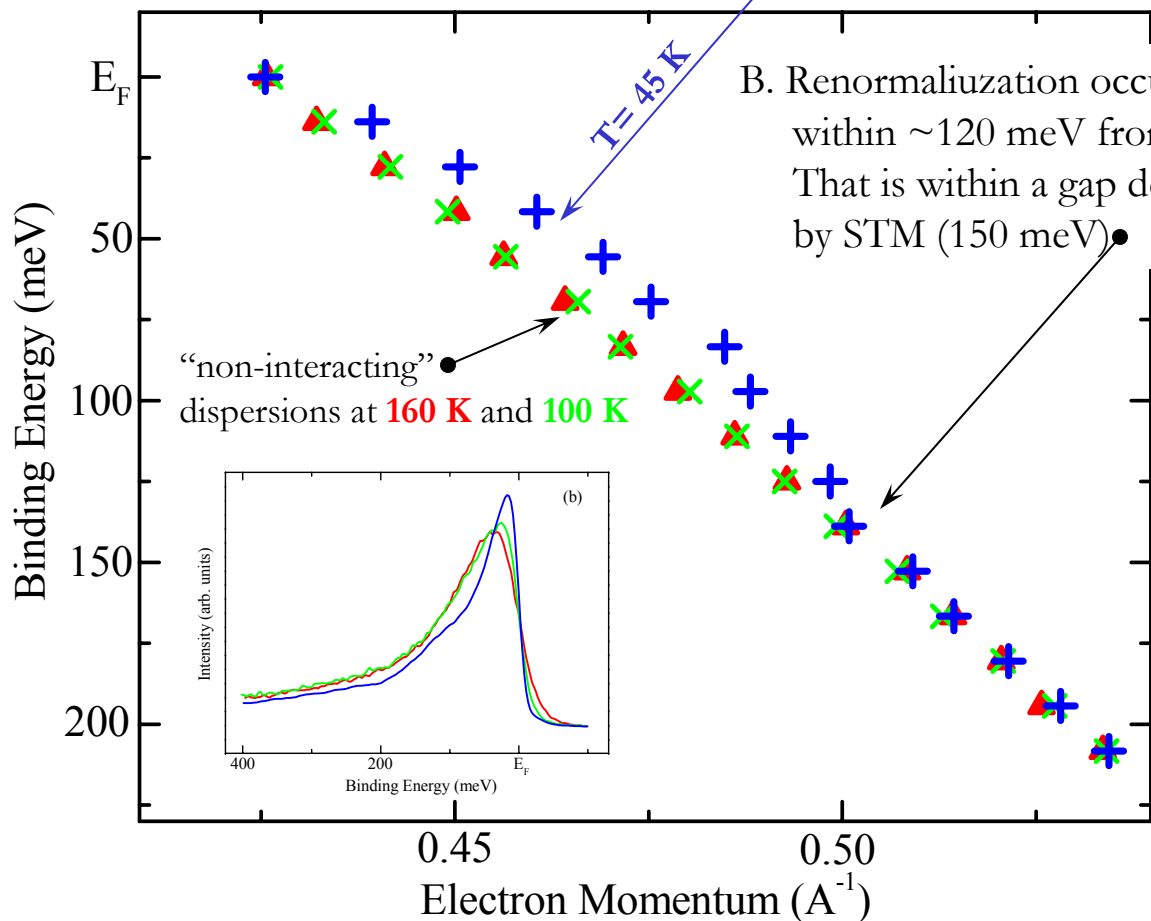


What is this collective mode?

/few clues from dispersion relations/

A. When CDW is commensurate with the lattice

“Renormalization” of dispersion becomes obvious



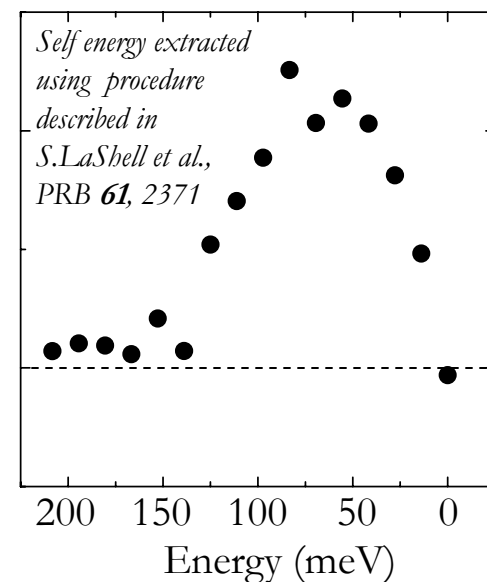
B. Renormalization occurs

within $\sim 120\text{ meV}$ from E_F

That is within a gap detected by STM (150 meV)

C. Real part of the self energy

peaks at $\sim 80\text{ meV}$, again within a CDW gap



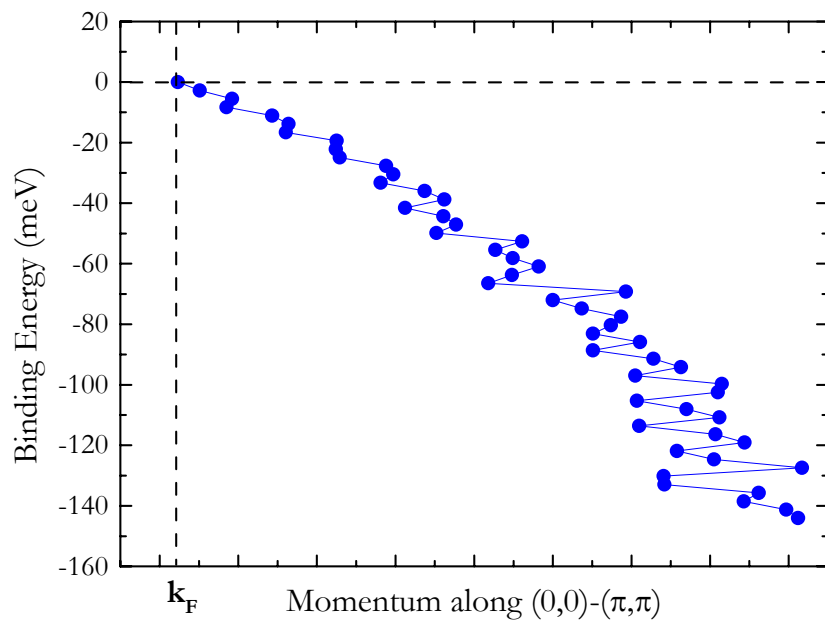
It is an exciton-like mode, perhaps...

Is 2H-TaSe₂ similar to the HTSC?

/of course not, however.../

Dispersions relations in underdoped ($T_c=80$ K) Bi₂Sr₂CaCu₂O₈
along (0,0) to (π,π) /gap node/

A. Normal State, T=120 K



B. Superconducting state, T=45 K

